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# Microstructure Evolution of A390 Al alloy by High Power Ultrasound Injection into Melts

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## 1. Introduction

A390 aluminum alloy is one of the most commonly utilized casting alloys because of high durability on abrasion, good castability, high strength to weight ratio. These properties make it possible that the alloy has been applied to automotive cylinder heads, engine blocks, and aircraft components. Silicon in the alloy is the most important alloying element to decide the various mechanical properties, however, the coalescence of the silicon during solidification makes various properties of the alloy degrade, and the coalescence must be controlled. The addition of copper-phosphorous alloy (CuP) as refinement process to suppress the coalescence of silicon has been adapted for last decade years. But the addition of the alloy has shown that low addition yield, non effective refined property and high cost. The application of the ultrasound for refinement of primary phase, especially Si, has been proposed and studied. The study results show that the refinement could be only achieved by the ultrasound injection into solid-liquid co-existence state which is in the sequence of solidification or the state in metal slurry. The mechanism of the refinement was proposed for the fragmentation of the dendrite of solid by the cavitation effect and acoustic streaming of the ultrasound, however, there are a lot of experimental results not to explain as the fragmentation mechanism. In this study, new concept for refinement of Si in A390 alloy was proposed that the adaption of the ultrasound injection horn which can be source of the supplement of the heterogeneous nuclei. The ultrasound horn has been coated or protected to prevent from infiltration into melts until now. But, in this study, the horn for injection of ultrasound was used as the source of the nuclei of A390 alloy melts.

## 2. Experimental procedure

Table I shows the chemical composition of A390 alloy and Table 2 is the experimental conditions for ultrasound injection into alloy melts. The ultrasonic frequency of the apparatus is 20 kHz and the maximum power output is 1,200W. About 500 g of A390 alloy ingots were melted in graphite crucible, when the temperature of the melt reached

Table I. Chemical composition (wt%)

| Si | Cu | Mg | Mn | Fe | Al |
|---|---|---|---|---|---|
| 16.9 | 4.3 | 0.5 | 0.1 | 0.1 | Bal. |

Table II. Casting and ultrasound conditions

| Alloy | A390 |
|---|---|
| Melting temperature, °C | 750 |
| Mold holding temperature, °C | 150 |
| Ultrasonic frequency, kHz | 20 |
| Ultrasonic power, W | 1,200 |
| Ultrasonic injection time, min | 0, 1,3, 6, 10, 20 |

experimental condition, then the preheated injection horn was dipped about 20 mm in the alloy melt. After ultrasonic injection, the melt was cast in a steel permanent mold. The ultrasound injection time was 1, 3, 6, 10, 20 minutes at each condition to obtain the microstructure evolution with increasing injection time.

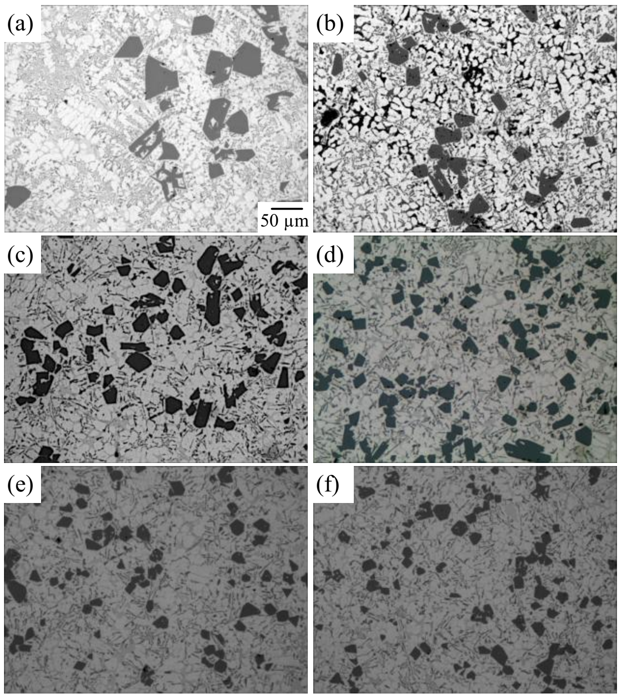


Fig. 1. Microstructure of A390 alloy with and without ultrasound injection in melt:
(a) without injection, (b) 1 min, (c) 3 min, (d) 6 min (e) 10 min and (f) 20 min.

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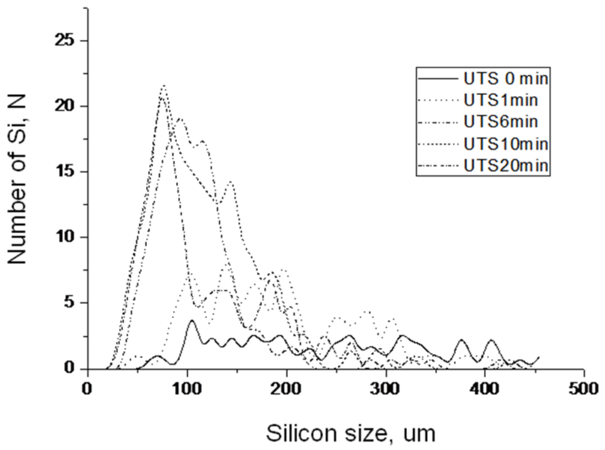


Fig. 2. Distribution of primary Si for sample cast with and without ultrasound injection

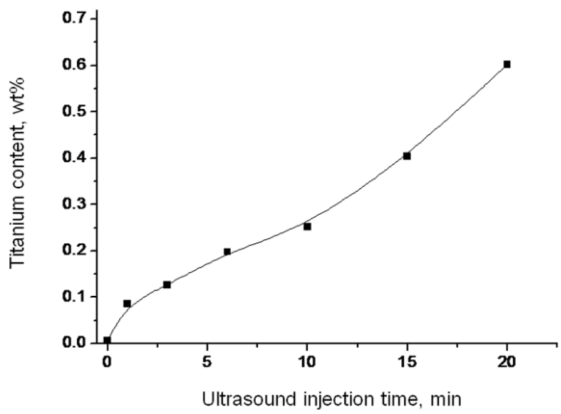


Fig. 3. Titanium content in A390 melts with increasing ultrasound injection time

**3. Results and discussions**

The optical micrographs of the samples from castings cast with and without ultrasound injection into alloys melts are shown in Fig. 1, and Fig. 2. shows the image analysis results of the Si size distribution of the samples at each experimental condition. The microstructure refinement, especially primary Si phase, could be achieved in all samples with ultrasound injection, the size of Si is more smaller and dispersed uniformly in alloy matrix with increasing injection time as shown in the figure. Fig. 3. shows the microstructure of A390 alloy cast with ultrasound injection for 10 min. and the microstructure of the sample after re-melting and casting at same experimental condition without ultrasound injection in melts. As shown in Fig. 3, the effect of ultrasound injection on the refinement of Si was not disappeared by re-melting and casting, and this means that the refinement mechanism could not be explained by the fragmentation theory of the dendrite particles which can be melted and disappeared during re-melting. The result in this study shows that the heterogeneous nuclei which were dispersed in alloy melts by ultrasound injection and were not soluble could be remained and promoted the Si refinement. In this experiments, commercial purity titanium was used as the horn material and the titanium atoms or clusters could be wetted and dispersed in alloy melts, and these could be nuclei for heterogeneous nucleation of Si. Fig. 4. shows titanium content of A390 samples with ultrasound injection time. Almost alloying elements except for titanium were not varied with ultrasound injection time and only titanium content was increased with time. The titanium could be reacted with aluminum and formed the intermetallic compound, $Al_3Ti$, which could be acted as heterogeneous nucleus of Si.

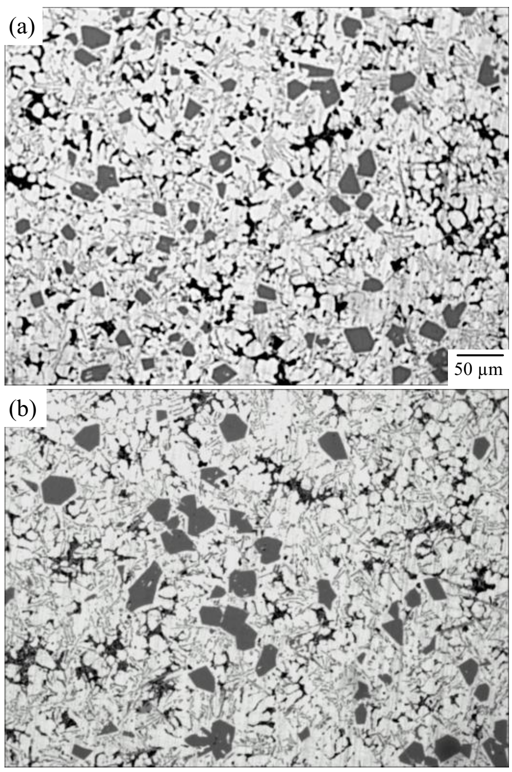


Fig. 3. Microstructure of A390 alloy (a) ultrasound injection for 10 min and (b) after re-melting the sample (a)

**4. Conclusion**

The present investigation attempts to explain the mechanism of ultrasound injection on the grain refinement of A390 alloy. This is because that the distribution of heterogeneous nuclei in melts by ultrasound injection with titanium horn.